DOCUMENT RESUME

ED 300 239 SE 049 754

AUTHOR	Stage, Elizabeth; And Others
TITLE	Can We Stand and Deliver? Mathematical Literacy in the Workplace.
INSTITUTION	Education Writers Association, Washington, DC.
SPONS AGENCY	Institute for Educational Leadership, Washington, D.C.; John D. and Catherine T. MacArthur Foundation, Chicago, IL.
PUB DATE	88
NOTE	28p.; Paper and Comments presented at the Annual Meeting of the Education Commission of the States (Baltimore, MD, August 11, 1988). A paper commissioned by the Media Resource Project on Literacy of the Education Writers Association.
AVAILABLE FROM	Education Writers Association, 1001 Connecticut Avenue, NW, Washington, DC 20036.
PUB TYPE	Speeches/Conference Papers (150) -- Viewpoints (120)
EDRS PRICE	MF01 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS	*Elementary School Mathematics; Elementary Secondary Education; *Mathematical Applications; Mathematics Curriculum; *Mathematics Education; *Mathematics Instruction; *Mathematics Skills; *Secondary School Mathematics; Teacher Effectiveness; Teaching Methods

ABSTRACT

This document, prepared for a seminar for education reporters, consists of a presentation followed by reactions from three other persons. The presentation first considers mathematics literacy from the perspective of future workforce needs. The requirements for many jobs are increasing due to the introduction of technology, while an informed citizenry needs increased quantitative reasoning skills for such things as reading a newspaper and analyzing voter information. The need for a changing mathematics curriculum and changing classroom instruction, with the emphasis on understanding, is discussed, but the barriers to change are also considered, with a number of illustrations. The role of education reporters in developing public awareness of the need for change is then noted. Reactions and additional comments include other illustrations of the changing role of mathematics in the workplace and society. (Twenty-seven references are listed.) (MNS)

Can We Stand and Deliver?

Mathematical Literacy in the Workplace

By Elizabeth Stage

with comments by
Stuart Rosenfeld
Tom Sciance
and
Sheila Sconiers

A paper commissioned by the Media Resource Project on Literacy of the Education Writers Association in cooperation with the Institute for Educational Leadership under a grant from the John D. and Catherine T. MacArthur Foundation.

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Published 1988
Printed in the United States of America

The Education Writers Association (EWA), founded in 1947, is the professional association of education reporters and writers. Its project on literacy was established to help journalists cover the issue of illiteracy/literacy in ways that reflect the complexities and far-reaching implications of the issues. This paper, one of several commissioned by EWA during 1988 that deal with specific facets of literacy, was first presented on August 11, 1988, at the annual meeting of the Education Commission of the States in Baltimore, Maryland. It was prepared to look at math literacy from the perspective of future workforce needs. Other papers look at the positions of the presidential candidates on education and literacy, literacy in the context of the newspaper reading habits of young adults, and the reporting on and coverage of literacy and poverty in the United States. EWA maintains a clearinghouse of resources on literacy and publishes a monthly newsletter, *The Literacy Beat*. The staff is prepared to help writers make contacts or otherwise obtain ideas and information about the issue of literacy. Please contact Lisa Walker, executive director, or Anne Lewis, consultant, at 1001 Connecticut Avenue, N.W., Washington, D.C. 20036; (202) 429-9680.

The views expressed herein do not necessarily reflect those of the staff and officers of the Education Writers Association, the Institute for Educational Leadership, or the John D. and Catherine T. MacArthur Foundation.

ABOUT THE AUTHORS

Elizabeth Stage is director of mathematics education at the Lawrence Hall of Science in Berkeley, California. Ms. Stage has served on California's textbook adoption policy board and is active nationally in mathematics education. A former junior and senior high school mathematics and science teacher, Ms. Stage also currently serves as the director of the Bay Area Math Project, one of 16 sites of the California Math Project.

Stuart Rosenfeld is deputy director of the Southern Growth Policies Board and the director of the Southern Technology Council. An engineer and management scientist for the General Electric Company, he entered the field of education as the director of a private alternative school in Vermont, later becoming a senior associate with the National Institute of Education in Washington, D.C. Mr. Rosenfeld has written extensively on education, economic development, and technology policy.

Tom Sciance, a chemical engineer, works in the Corporate Research and Development Planning Division of E.I. DuPont de Nemours and Company. Mr. Sciance served on the National Research Council of the Mathematical Sciences Education Board from 1985 to 1987, and is a member of the advisory boards for the engineering schools at Duke and Rice Universities, and the Advisory Committee on Chemical Engineering at the University of Oklahoma and Texas A&M University.

Sheila Sconiers is the director of Teacher Development, Elementary Component, University of Chicago School Mathematics Project, a professional development project for elementary and secondary school mathematics teachers in the Chicago Public Schools. She has taught both elementary grades and 8th grade science in the Chicago Public Schools.

Can We Stand and Deliver?

MATHEMATICAL LITERACY IN THE WORKPLACE

ELIZABETH K. STAGE

The National Assessment of Educational Progress (NAEP) recently released *The Mathematics Report Card: Are We Measuring Up?*[1] The media gave mixed answers to the question. The *New York Times* story carried the headline, "Schools' Back-to-Basics Drive Found to Be Working in Math,"[2] while *Time Magazine's* coverage was headed, "Flunking Grade in Math."[3] I know that reporters are not responsible for writing their own headlines, but the tenor of the articles differed considerably. Could both reporters have based their stories on the same official publication?

On the one hand, it is true that the back-to-basics movement has brought progress on the lower order skills of computation, at the same time as calculators have diminished their practical value, on the other hand, the mathematics education community's goal of achieving progress on the higher order skills, accelerated by the presence of the same electronic devices, has not been fully realized by the educational system nor embraced by the public at large. The failure of either of these articles, or any others I've seen to date, to get inside the data and to understand its complexity, is what brings me here today.

"It has been pointed out that the number of jobs requiring more sophistication may be fewer than the number of new jobs in service and fast food sectors, but it is certainly important for people to realize that the requirements for many jobs are increasing due to the introduction of technology."

If I had been assigned the NAEP story, I would have asked the following questions: Don't you think it odd that nearly all of the students tested reported owning a calculator, yet fewer than one-fourth of them use calculators in mathematics class? Does it surprise you that high school students in the upper quartile used calculators more frequently than those in the lower quartile—on homework (65% vs. 39%), for routine computation (49% vs. 21%) and on tests (49% vs. 17%)? Should you be concerned that nearly one-third of the 11th graders who were tested do not agree with the statement, "I usually understand what we are talking about in mathematics?" or that fewer than one-half of our secondary students expect to work in an area that requires mathematics?

What proportion of our students should expect to use mathematics in their jobs? What kinds of mathematics will they need to function as citizens? How will we prepare them for their adult lives? With respect to these issues, I will examine the ways in which the workplace and society are changing, our options for responding, the potential barriers to success, and the ways that reporters can help.

How is the workplace changing?

A favorite example comes from Sue Berryman, Director of the National Center on Education and Employment at Teachers College, Columbia University. She found that computerization in the insurance industry has caused five distinct jobs—messenger, file clerk, customer assistance clerk, claims adjuster, and policy writer—to be folded into one. More important, "the skills required to perform this job are greater than those associated with any one of the original five jobs." And, "the person needs less specific and splintered knowledge and more systematic and abstract knowledge.... He or she also needs to be able to frame answers to less standardized requests."[4]

Examples of upgraded jobs are found in many industries. People in formerly clerical desk jobs in banks now need a broad understanding of the increasingly complex array of the bank's financial services. Assemblyline workers now need to operate robots and to interpret information from graphs. Secretaries in high tech firms that have adopted statistical processing controls now need enough understanding of statistics to sample and evaluate their own work. It has been pointed out that the number of jobs requiring more sophistication may be fewer than the number of new jobs in service and fast food sectors, but it is certainly important for people to realize that the requirements for many jobs are increasing due to the introduction of technology.

It is possible that the technology will get smarter and smarter, eventually replacing the people who are now in the position of monitoring and interpreting the outputs of technology. An Office of Technology Assessment report gave the following stark dichotomy:

> There appears to be no necessary link between production technology and the kinds of jobs created. Both manufacturing and office work can be upgraded or sharply downgraded as the result of new equipment. Clerical office workers can become upgraded to take on new responsibilities—becoming "parapublishers," "paralibrarians," and "paramanagers"—or their jobs can be reduced to mindless data entry.[5]

The OTA analysis indicated that the direction taken will be one of many public policy decisions that can and should be made intentionally. One factor in such decisionmaking is the ability of our educational system to respond, to produce more flexible, better educated workers. The workplace is not the only client of the educational system, however, and the literacy requirements of society as a whole also have increased in the face of increased technology. I would expect this audience to agree with Thomas Jefferson, who said:

> Were it left to me to decide whether we should have a government without newspapers, or newspapers without a government, I should not hesitate a moment to prefer the latter. But I should mean that every man should receive those papers and be capable of reading them.

Why do I believe that quantitative reasoning is necessary to read a newspaper? There are humorous examples of the misuse of statistics, such as understanding how Pittsburgh ended up ahead of San Francisco in the Rand McNally *Places Rated Almanac* as the most desirable place in the United States to live. The ranking was due to the summation of ratings, such that one 1st and one 29th place, equalling 30 points, would be equated to a pair of 15th places.[6] Or, how did Beverly Hills qualify as a distressed city on a U. S. Department of Housing and Urban Development list? It was due to slow population growth, slow employment growth, and more than 20% of its housing being constructed before 1940.

"...you cannot pick up a San Francisco newspaper without reading a story about acid rain or earthquakes. The pH scale by which acidity is measured and the Richter scale by which earthquake intensity is measured are logarithmic scales. You cannot understand the story unless you understand that a reading of '5' is one-tenth the value of '4' with respect to acid rain and that '5' is 10 times the value of '4' for an earthquake."

But more seriously, you cannot pick up a San Francisco newspaper without reading a story about acid rain or earthquakes. The pH scale by which acidity is measured and the Richter scale by which earthquake intensity is measured are logarithmic scales. You cannot understand the story unless you understand that a reading of "5" is one tenth the value of "4" with respect to acid rain and that "5" is 10 times the value of "4" for an earthquake. Or, consider last week's desegregation case in Yonkers, where the judge fined the city $100 for the first day of defiance of his order, $200 for the second day, $400 for the third day; by September 8th, the fine would have reached $1,638,300.

"From the analysis of the workplace coupled with the requirements for an informed citizenry, then, there are no options. We must recognize that schools must prepare students for an increasingly demanding world. The ability to make sense of quantitative information and to respond flexibly to change are prerequisites to obtaining and retaining a job, even in a traditionally non-quantitative field, and to reading the newspaper with understanding."

Another important aspect of functional literacy is being able to read and understand information provided to voters. The voter information pamphlet distributed by California's Secretary of State to all registered voters provided the following information. The proponents of the School Facilities Bond Act of 1988 dramatized the fact that 140,000 new students are entering California's public schools each year by saying, "Housing these new students means building an average of 10 new classrooms every day, seven days a week, 52 weeks a year."[7] The estimate given for the number of classrooms, when divided into the number of students, yields an estimated 38.5 students per room, certainly an economically conservative estimate. The opponents of the proposition dramatized their position by noting that one California school district spends $4,582 per employee per year for a health plan that covers cosmetic surgery. Is $4,582 excessive? Is it relevant? Unfortunately, the opponents' tactic of intimidation with irrelevant numerical information did not discredit them; they prevailed!

From the analysis of the workplace coupled with the requirements for an informed citizenry, then, there are no options. We must recognize that schools must prepare students for an increasingly demanding world. The ability to make sense of quantitative information and to respond flexibly to change are prerequisites to obtaining and retaining a job, even in a traditionally non-quantitative field, and to reading the newspaper with understanding. Fortunately, we know what to do.

The Changing Math Curriculum

What do you think of when you remember mathematics in school? Endless pages of addition, subtraction, multiplication, and division problems? And did you look forward to doing word problems? When you were trying to memorize the rule for the division of fractions, did someone try to reassure you that it was important because you would need to know how to do this "when you're an adult"? In fact, now that you're an adult, do you ever need to divide fractions? And what does this have to do with the requirements of a technological society?

The math curriculum is changing. If you were to go into a classroom today, you should see it as a more lively and interesting place than you remember. Instead of endless drill with paper and pencil, students should be investigating situations in which mathematical ideas are evident. They should also be working with real objects to act out ideas, using graph paper and drawings to represent situations. They might not even be using numbers! They should be talking with one another and the teacher, writing about their thinking, and asking questions. They should have time to think, the opportunity to guess without fear of being laughed at, and the encouragement to persist. They should be able to explain to you what they are doing and why.

"Children do need to learn the basic ideas of math—the meaning of addition, subtraction, multiplication, and division—and they need to know a set of basic arithmetic facts. Experience with a calculator can frequently help a student to develop these ideas. It's not a matter of 'either basics or calculator,' it's a matter of both."

At the youngest ages (K-3), children should be doing activities that build an understanding of math concepts—When do you add? What's the relationship between addition and subtraction? Rather than practicing quick recitation of math facts, children should be counting real objects, talking with other children, and drawing pictures to represent their ideas.

In the intermediate grades (3-6), children should be learning the paper-and-pencil methods only after they have a good sense of the processes. They should still be using concrete objects like counters and base-ten blocks to model the relationships in the computational situations, and calculators should always be available for lengthy computations. They should be talking with other students so they have the chance to share their ideas, to have their questions answered and their answers questioned.

At the middle-school grades (6-8), students' experiences with numbers should extend to very large and very small numbers by using exponents and decimal notation. In addition to discussion in groups, communication of mathematical ideas also should take place in writing. Materials such as geometric objects, pattern blocks, and fraction bars should be used to support the development of the more abstract ideas of the middle school curriculum. Problems should be more complex and involve a variety of procedures and tools.

Even at the high school level, students should be working in groups and using concrete models to make abstract ideas more accessible. Everyone, but especially at the junior high and high school levels, should be using calculators whenever they have tedious computations to do. Children do need to learn the basic ideas of math—the meaning of addition, subtraction, multiplication, and division—and they need to know a set of basic arithmetic facts. Experience with a calculator can frequently help a student to develop these ideas. It's not a matter of "**either** basics **or** calculator;" it's a matter of both. Finally, students should be having fun. A playful and relaxed atmosphere is more conducive to learning than a tense and formal one.

This description of what the classroom should look like comes from the draft of a brochure that I wrote for the California State Department of Education. The formal curriculum document on which it is based, the *Mathematics Framework*,[8] has been echoed in three national projects. The Mathematical Sciences Education

"For many people mathematics is a narrow train laid along a track. The ordinary people ride through addition, subtraction, multiplication, and division of whole numbers, fractions, decimals, and percents. The more persistent stay on board through algebra, geometry, trigonometry, and calculus. Almost nobody knows the names of what comes next, and nearly everyone hates statistics."

Board has a Curriculum Task Force which is developing a framework for what the K-12 curriculum ought to be by the year 2000. Their draft report emphasizes the development of mathematical power rather than the development of routine skills.[9] The National Council of Teachers of Mathematics is undertaking parallel work; their draft *Curriculum and Evaluation Standards for School Mathematics* also talks about mathematical power as the ability to explore, conjecture, and reason logically, as well as to use a variety of mathematical methods effectively.[10] The American Association for the Advancement of Science is engaged in a somewhat broader effort to redefine scientific literacy, in part to include not only science but also mathematics, technology, and the social sciences. The enterprise is called Project 2061 as a way of noting that the report, *What Science is Most Worth Knowing?,* focuses on science knowledge bounded by the recent and next-scheduled passing of Halley's Comet. Also a draft, it recommends the ability to recognize signs of weak arguments as a mathematical skill and recommends against computation with rarely encountered fractions, such as sixths and sevenths.[11]

We are well on our way as a professional community to establishing a new set of goals for mathematics education that are much closer to the literacy needed for the 21st century. We are even seeing them translated into regulations. The California mathematics textbook standards, for example, require students to solve problems that present new and unexpected situations and to select among estimation, mental arithmetic, paper-and-pencil, and a calculator to achieve a computational result. This spring, the Federal Chapter 1 regulations for programs for disadvantaged youth added higher order thinking skills to the list of desirable outcomes.

Yet, what will you see if you walk into a mathematics classroom, even in California? Rows of students working individually with paper and pencil or groups of students working cooperatively with real objects? An emphasis on rules and procedures for getting the right answer or an emphasis on understanding many ways to arrive at good solutions? A silent, teacher-centered classroom or a noisy, student-centered classroom? If we know what to do, why aren't we doing it?

Barriers to change in education are our stock in trade. Before I go through the litany of texts, tests, teachers, tracking, and resources, though, my argument begins with the need to reconceptualize what mathematics is. For many people mathematics is a narrow train laid along a track. The ordinary people ride through addition, subtraction, multiplication, and division of whole numbers, fractions, decimals, and percents. The more persistent stay on board through algebra, geometry, trigonometry, and calculus. Almost nobody knows the names of what comes next, and nearly everyone hates statistics. The smarter you are to start with, the faster you go and the farther you get. Most people get off the train as soon as they think they can get away with it; in fact, after the first year of algebra we lose one-half of the passengers each year until we end up with only 700 Ph.D.s, half of whom are not United States citizens.

Consider the experience I had on a Saturday evening radio call-in program this spring:

> Caller: What's the big deal about mathematics? I took math through calculus and I never use it.
> EKS [confident that she can find the mathematics in any occupation]: What is your occupation?
> Caller: I'm a scientist in Silicon Valley.
> EKS [somewhat surprised]: Do you gather data, make inferences about data, try to communicate about the data to other people?
> Caller: Yes.
> EKS [greatly relieved]: Well, that's what I mean by mathematics!

This incident is understandable, since today's mathematics is very different from what it was 25 years ago when most of today's scientists studied mathematics, but it underscores the prevalence of the characterization of mathematics that I described.

The several problems with this conceptualization each must be examined and addressed before we make any real progress with achieving the redefined mathematical literacy that we need. First, the narrow track from arithmetic to calculus must be replaced with a map that clusters and interconnects geometry and measurement, statistics and probability, patterns and functions, logic, and numerical analysis. These various domains all have roots in concrete and intuitive experiences that can and should be studied by young children as well as by adults. (Yes, that means statistics in the third grade!) Second, the notion that mathematics achievement is a function of native ability must be set aside. The Japanese, against whose achievement we are constantly being compared and to whom we attribute greater native ability, believe, instead, that hard work is the key to mathematics achivement.[12]

"An even broader consequence of this view of mathematics as a narrow, linear, trackable subject has been its use as a social sorting mechanism. It's been more than a decade since Lucy Sells coined the phrase 'critical filter' to describe the role of mathematics in educational and career outcomes, and we are still working overtime to dismantle it."

Our incorrect insistence that mathematics is a function of native ability leads to widespread use of ability grouping, or tracking. As Jeannie Oakes points out, tracking does **not** accomplish its stated aim of increasing achievement; if anything, it systematically decreases the achievement of students in lower tracks. It does **not** accomplish its stated aim of making slower students feel better about themselves; it does label kids as high achieving, bright, smart, quick, and in the eyes of many, good; or, slow, below average, and dumb. It is **not** founded on accurate or fair placement; it is closely related to race and class. Oakes' observations of high-track mathematics classes are much closer to the ideal that I described, an emphasis on thinking and reasoning, while she found that low-track classes focused grade after grade on basic computational skills and arithmetic facts—multiplication tables and the like, skills made useless by technology. Mathematics is more thoroughly tracked than any other subject, with more consequent damage.[13]

"The increased funding for mathematics and science especially, and education generally, in the five years since A Nation At Risk, however, has been spent, by and large, on more of the same—more hours, more days, more courses, but the same material."

An even broader consequence of this view of mathematics as a narrow, linear, trackable subject has been its use as a social sorting mechanism It's been more than a decade since Lucy Sells coined the phrase "critical filter" to describe the role of mathematics in educational and career outcomes, and we are still working overtime to dismantle it.[14] She was concerned with the inadequate preparation of female and minority students, many of whom had taken enough mathematics courses to be admitted to the University of California but too few to be eligible for the first course offered by the Mathematics Department, and thus, were excluded from most fields of study. Medical schools and business schools require calculus for admission, which is desirable but not necessary background, yet the requirement screens out thousands of students.

Universities are not the only institutions that use mathematics as a way of screening people out, however. Some of the more popular trades with apprenticeships have begun to use high school mathematics, such as algebra. Banks, which never allow tellers to compute by hand, routinely use paper-and-pencil arithmetic tests to screen potential employees. The persistent belief that unassisted computation is a valuable commodity is appropriately ridiculed in an editorial called "Hazing" in the *Grady Report,* in which David Grady concludes, "To confuse maintaining standards with refusing to let go of obsolete habits is to confuse hazing with education. Surely we can do better by our children—and our aspiring professionals—than that."[15]

Intervention programs have identified educational strategies for increasing the participation and achievement of female and minority students in mathematics-based fields of study and work,[16] but we face an uphill battle against the incorrect notion that certain people just can't learn mathematics. Why we need to expand our notion of who can succeed in mathematics to include everyone is well summarized by Lorna Rounds, associate superintendent in the Los Angeles Unified School District, who said, "There is no slow version of the *New York Times.*"

What else stands in the way?

Once we have reconceptualized mathematical literacy and made the commitment to achieve it for all students, what else do we need? Mathematics appears to get a reasonable share of instructional resources in terms of time—an average of 45 minutes per day in elementary and secondary schools[17]—and materials purchases—about 18% of the textbook dollar.[18] Of course, education gets a paltry share of resources for change. We spend about 2.5% of our Gross National Product on research and development, but only .025% of our educational expenditures on educational research and development. California's largest state-funded staff development program is in mathematics; it gets $1.2 million per year and is able to serve less than one-half of one percent of the 92,000 teachers in the state who need to learn how to teach new content with new methods.

The increased funding for mathematics and science especially, and education generally, in the five years since *A Nation At Risk*, however, has been spent, by and large, on more of the same—more hours, more days, more courses, but the same material.

The way these resources are spent must be questioned. International comparisons show the major difference between our curriculum and that of the industrialized countries that perform at a higher level is the way our curriculum is organized. The American curriculum, characterized as "low intensity," covers many topics each year with equal emphasis. In France or Japan, a particular topic is studied thoroughly in one year, a "high intensity" curriculum, with the result that a greater proportion of students learn the material in the year in which it is introduced.[19] Another way of describing the American curriculum is that it is repetitious (one study has shown the paucity of new material in the elementary grades).[20]

The way the curriculum is organized in classrooms is determined to a substantial extent by the tests used to measure performance. It is generally **not** recognized that:

> Standardized test items are chosen to best spread students' scores out along the normal distribution. Items that are too easy—implying successful mastery—do not appear. Conversely, items that are more difficult—often because of inadequate readiness—are frequently used because they most effectively discriminate among students. The result is an astoundingly poor match between these tests and most textbooks.[21]

As an article in *Learning* describes, the results of standardized testing go from the board of education to the superintendent to the principals to the teachers, so that teachers force skills, prematurely, to students one or two grades ahead of the time that they know the students will be successful in learning.[22]

Increased funding for education has brought increased demands for so-called accountability. As the OTA said:

> The perpetual problem of management in education is that the system tends to reward results that can be measured (and therefore make progress in what can be measured) while the most important products may go unmeasured.[23]

"When research studies or tests are accepted as valid indicators of achievement without asking whether they are testing the right things, reporters are yielding to the apparent authority of data and failing to get the story."

For a devastating critique of testing in general, see S.J. Gould's *The Mismeasurement of Man.*[24] And, in mathematics, particularly, a panel of the National Research Council concluded:

> Currently available multiple-choice tests are adequate primarily for assessing student learning of the declarative knowledge of a subject. They are not adequate for assessing conceptual knowledge, most process skills, and the higher-order thinking that scientists, mathematicians, and educators consider most important.[25]

There are, of course, other influences on the mathematics curriculum that must be brought into alignment with the new definitions of mathematical literacy. Staff development to allow teachers to learn the new material and methods of teaching is greatly needed but can only go so far until the materials they use, including tests, are improved, and until the parents of their students begin to support the new curriculum. Models exist for staff development and parent education, however, so that public awareness is the major unconquered barrier. That's where education reporting comes into play.

I believe that what you do matters. Do you recall a story that carried the headline, "Math and Sex: Are Girls Born with Less Ability?"[26] The damage that resulted from that story, linking sex differences in mathematics achievement to inherited factors, was inadvertently documented by researchers at the University of Michigan who were studying the relationship between parental attitudes and student performance. They found that the beliefs of mothers about their own daughter's mathematics ability were negatively influenced by exposure to media coverage of research findings, independent of their daughter's actual performance in mathematics.[27]

When research studies or tests are accepted as valid indicators of achievement without asking whether they are testing the right things, reporters are yielding to the apparent authority of data and failing to get the story. The NAEP results should, in this configuration, have been reported as discouraging. But what are the stories that surround the NAEP report?

I was initially reluctant when I heard "Stand and Deliver" in the title of this seminar. Competing with the powerful images created by the popular film that portrays the success of Jaime

Escalante and his students at Garfield Senior High in Los Angeles, in achieving spectacular success in calculus, is nearly impossible in a solely verbal medium. Yet, it provides me with two important points for this audience. First, in the papers I read, the story of this film was treated as as entertainment story. The film review was accompanied by a story about Edward James Olmos, the star of the film, and the risk he took by making a film about calculus. The story of Jaime Escalante, the hero of the story, and the risk he took by believing that the kids at Garfield could learn calculus, remained for the theater. Some of the important elements of Escalante's success, such as his humor, commitment, and belief that poor, minority kids can learn, came across clearly.

"There is a critical need to reconsider and redefine mathematics education. Reporters can make a valuable contribution by asking questions that provoke people to go beyond simplistic test scores and look at what is important to teach, to test, and to learn."

Other important elements of Escalante's program, such as using concrete models to make abstract ideas meaningful and concentrating attention on the most important issues, instead of covering the waterfront of detail, were lost in the drama and remain to be uncovered by some investigation. These are the educational issues that you can and must cover. A deep understanding, that most students respond well to programs that challenge them, in the face of widespread practice that demonstrates they do not respond well to programs that dwell on their weaknesses, needs to be lifted out of the drama for all to see.

That's old news, but I've got some things that are coming up that you may want to take a look at. This fall, new seasons of two television programs will be broadcast on PBS, "The Voyage of the Mimi" and "Square One TV." They embody some of the ideas I've been talking about, so I hope you write an education piece that can run parallel to the entertainment editor's coverage. How do they portray mathematics? What are the reactions of kids, parents, teachers? Are they being used in schools? Why or why not?

This year the reports of the American Association for the Advancement of Science, the Mathematical Sciences Education Board, and the National Council of Teachers of Mathematics will be released. It is an opportunity to examine the curricula at state and local levels to see if they are attuned to the issues in this paper. Have school administrators and teachers reconsidered their mathematics curricula? Why or why not? Are staff development programs, instructional materials, and testing programs being realigned with the new curriculum goals? Are school boards and parents leading the way or are they obstacles to be overcome? There is a critical need to reconsider and redefine mathematics education. Reporters can make a valuable contribution by asking questions that provoke people to go beyond simplistic test scores and look at what is important to teach, to test, and to learn.

Comments

Stuart Rosenfeld

I'd like to make just three points in the time that I have. First, based on a study we've just completed on automation in the rural South, math literacy is critically important to employment. Second, with respect to the workplace, math literacy is more than just adding and subtracting numbers. It's an understanding of relationships—what some call critical thinking. Third, mathematical illiteracy is high because math's value has not been fully appreciated in the schools, and that's been especially true in vocational education. But there is something we can do about it.

Over the past year and one half, the Southern Growth Policies Board has been looking at the conditions that surround automation in the rural South, including the effects it has on skills, knowledge, organization and hiring practices. In addition to surveys of companies, we conducted eight on-site case studies of plants that were introducing process technologies.

We began by reviewing the literature and especially the debates about the skilling and de-skilling of work by automation. What we found confirms the point Elizabeth Stage makes. Work today *does* require higher-order thinking skills and higher levels of educational abilities, not less. I will use manufacturing as an example.

Why is this true, if automated machines are so smart and processes are pre-programmed? There are a number of explanations, most of which are based on two facts: that work is organized differently and that different things are expected of workers. Most innovations are small improvements to a technology in place performed by workers who fully understand its potential. The other fact is that technology is imperfect and requires close monitoring, adjustment, and correction.

There are several organizational issues related to the new emphasis on quality. Producers formerly used sampling methods to monitor quality and hired inspectors to report reject rates. Today business wants *no* failures. Under these conditions, each operator becomes responsible for quality control and has to understand basic concepts of statistical quality control.

Second, in a computer-integrated company, each person is expected to understand the entire manufacturing process. For employees to participate in operating decisions, as many firms now want, they have to be able to understand the basic economics of the production process, and that is expressed in quantitative terms.

Third, the actual work now involves numbers, not physical skill. I remember hearing Ray Marshall (former U.S. Secretary of Labor) speak just after he had returned from Japan a few years ago. He described the quality circles he observed where Japanese workers were using regression analysis techniques to discuss solutions to production problems. And understanding them.

Finally, many jobs such as machining require using numbers, setting dials or editing a program. A machinist on modern equipment does not simply manually move a piece of metal past a cutting tool; he responds to changes that are not observed visually but are read in a digital report or graph. An article in the *Wall Street Journal* last month claimed that 40% of one particular electronic component in today's auto engine returned to the company as defective were perfectly good. The problem was that the mechanics didn't know how to properly test for defects hidden inside a component. The conclusion was that there is a need for more technical skill, including math, for auto mechanics to obtain an associate degree.

We found that the major barrier to retraining at the eight sites we visited was not the inability to read. Most of the workers in the plants we visited could read. The problem was their inability to understand math and to perform simple manipulations with numbers. In seven of the eight sites, the companies had to provide very basic remedial math as part of their retraining. There is no way that workers can understand quality control or participate in decision-making without understanding math concepts. I'm not talking about sophisticated math that we never use. Management wanted workers who could solve problems, and they saw math skills as a way to measure problem-solving skills.

Jackson County, Kentucky, one of the case study sites, is well-known for having the highest illiteracy rate in the nation. In 1980, 62% of the adults had not completed 8th grade. Last year, a sophisticated automated manufacturing plant moved there. They knew they needed more educated people, but they were committed to hiring locally. So they invested heavily. They set up training shops a year before the plant intended to open, started with fractions and decimals and took the workers, believe it or not, through statistical process control—including probability, normal distributions, standard deviations, and control charts. They also taught them some basic chemistry and electronics. They prepared

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people to do any job on the production floor to increase flexibility. And the workers got their GEDs in the process.

I want to briefly mention my second point, that math is more than manipulating numbers. Apparently, some of us do not understand that. We talk about shortcomings in math in this country, but we don't discuss why math is important. To me the complexity of actual computations needed for math literacy are not the real issue. It is acquring the understanding of relationships and logic, measurements and orders of magnitude. Understanding the concept of exponential growth, even if you can't handle the calculations, and understanding relationships between 1,000 and 1,000,000 are important to being able to understand everyday occurrences. This is part of literacy today.

The last point is that the United States is way behind other industrialized countries. It ranks near the bottom on standardized tests given youth of the same age in various industrialized countries. But even international comparisons don't indicate the seriousness of the problem. The results of the latest NAEP tests which showed that one-half of the 17-year olds don't know whether 87% of 10 is more than 10, less than 10, or equal to 10 really shook me up. How do these people know how large a tip to leave at restaurants? The livelihood of workers in one of our largest occupations depends on understanding a percentage. On that same NAEP test I mentioned one-half of the 17-year-olds could not calculate the area of a rectangle given two sides. That is something that could be figured out logically without memorizing a formula that area equals width times length. Only six percent could calculate simple interest. Where will our entrepreneurs come from if no one understands interest?

Part of the problem is that we don't take math seriously for students not college-bound. If you look at the vocational education graduates of 1984, only one-fourth had taken any geometry and less than 2% had taken trignometry or physics. Physics, of course, is also math. Some vocational education advocates argue that these concepts are integrated into vocational courses. I think that **is** possible, but I don't believe that it is happening very often or very effectively. Vocational students have been shortchanged in math. One exception, in my opinion, is vocational agriculture. Vocational agriculture had to teach math and science because farming was an entrepreneurial activity. It included, agriculture, finance, measurements of productivity, and experimentation.

We have some of the same problems of low levels of math at the community college level. Curricula are being improved, but course titles alone don't always reflect the level of competencies.

Despite what I've just said about vocational education, I also think it could be one answer to math illiteracy. Courses that present real problems may provide the environment to get math concepts across more readily. But it means a different conceptual model for vocational education.

Thomas Sciance

I served on the Mathematical Science Education Board as a kind of consumer representative. Most of the people who work for the Du Pont Company use mathematics and the kind of thinking that comes with learning mathematics as part of their jobs—whether they are engineers, managers, mechanics, plant operators, or lab technicians.

Being on the board was a fascinating experience because of the variety and quality of the members. Listening to their discussions, I became convinced that solving the problems of mathematics education is a really critical national issue, going far beyond simple economic issues of direct interest to employers.

Certainly, cost is important. Having paid for one education for everybody, the public shouldn't really be burdened with the extra cost of having industry and the military do it again. And college educations are so expensive that it is a shame to have to spend the first year teaching remedial subjects that should have been learned in high school or earlier.

But the true cost of not learning mathematics early and well is much greater. Mathematics is a language. It is the language of science, technology, and economics. It is also a tool, like a piano or a shovel. If we want to remain a nation that leads the world in manufacturing or technology, or at all, we need to make sure more people are comfortable with the language and proficient with the tool. And that needs to be done as early as possible.

"But the true cost of not learning mathematics early and well is much greater. Mathematics is a language. It is the language of science, technology, and economics. It is also a tool, like a piano or a shovel. If we want to remain a nation that leads the world in manufacturing or technology, or at all, we need to make sure more people are comfortable with the language and proficient with the tool."

For some reason I do not understand, people who have no difficulty with the idea that their children have to learn to read no matter what, and who are willing to make them work at the piano for two or three years so that they will learn at least to appreciate music, don't feel that way about fractions. They should. The English language is a collection of symbols that lets us transmit and recall information. Mathematics helps us reason effectively, solve problems, and transmit and recall specific quantitative information.

All this is by way of reinforcing what Elizabeth Stage has said: mathematics, learned early and well, enables you to learn other things more easily and to use them effectively—things as

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ordinary as reading and understanding a newspaper, or knowing how much change to expect at the store, or as complex as the risk versus benefits of nuclear power or the effect of monetary and fiscal policy on inflation. Life seems to consist of a series of problems to be analyzed and solved. And if people are going to run a democracy well, they have to be able to understand issues and deal with a certain amount of complexity. Learning mathematics also develops the skills and thought processes needed to do these things, and as Stage emphasizes, to adapt to the inevitable change.

Okay, learning mathematics early and well is important and even vital to this country. We have considerable evidence that it isn't happening, and worse, that practically every other civilized country is doing a better job of it than we are. Now, we have a couple of problems to solve: first, we don't know exactly what to do about it; and second, if we did know, we have no convenient way to implement changes. We have 50 states and maybe 20,000 school boards, all doing their own thing with varying degrees of interest, competence and financial resources. There is not only little national leadership, but considerable resistance to any effort to supply it. There are a host of different interest groups involved, many with widely differing values—in fact, the major point of agreement often seems to be that the solution to the crisis is for the government to furnish more money so that it can do more of what it has been doing, faster. I don't claim to be an expert in education, but I have learned from experience that spending more money to do things that don't work, doesn't work. We need to to different things, in different ways.

If the United States is to continue to be a world power, we need excellence from those capable of achieving it. Many people are very relaxed about this, believing that "cream always rises to the top." They believe that if you take care of the average, the best will take care of themselves. Well, if you homogenize milk, cream does *not* rise to the top. That is the purpose of homogenization. Do *you* want a perfectly homogeneous population? I don't.

This is why I worry about eliminating all tracking, unless we have something to replace it that will force the better students to excel (not that I think our tracking works as well in that respect as it should). It is certainly true that learning mathematics or anything else is hard work. The general view of engineers is that if you don't understand something well enough to use it to solve problems, then you don't understand it. Being able to apply knowledge to solving problems is associated, at least in my mind, with working so many that you get sick of it, and then working some more. If you have a group of widely varying abilities, there is a natural tendency for the best to shift into neutral and coast. So I don't endorse a strong position against tracking of the sort that enables the best to do their best. (Does that mean I favor segregating kindergartners into groups according to an *a priori* assessment of their capability, thus stunting their development forever? Of course not.)

Another point of possible disagreement is the relevance of mathematical skills of the computational sort in the workplace. If Stage means that manually computing square roots should not be a criterion to employ a clerk, I agree. If she means being able to multiply six times seven, or knowing that it is the same as seven times six, I don't. Calculators have changed the way people work, but certainly have not eliminated the need for basic computational skills in the workplace.

It is true that tools affect the educational process. Engineers used to have to use slide rules for computation. A characteristic of slide rules is that they don't tell you where the decimal place is—they just give you the first three digits of the answer. So all engineers had to learn to make quick estimates of the order of magnitude of the answer of any calculation they were going to make on the slide rule. This had a good side effect in that you developed the habit of always mentally checking your answers against your general knowledge to make sure that they were reasonable. Calculators and computers, of course, eliminated the need to independently estimate the magnitude of the answer, but the habit itself was very valuable. You don't always know you put garbage in, so being able to recognize garbage out is an essential skill that many recent graduates haven't mastered.

Another example is that before the advent of computers, we spent long hours learning shortcut techniques or approximations to solve problems because rigorous methods were just too time-consuming. Now, with computers, we use rigorous techniques as a matter of course. What has happened, though, is that some of the old techniques have had to be retained as pedagogical tools—the computers give answers, but the students don't always understand just what they did to get them. And that is a deadly flaw because if you dont understand what you are doing in the workplace, you will eventually make a dangerous or expensive mistake.

Some of Stage's paper deals with standardized testing. It's a complicated subject, and certainly there are many shortcomings. What one might ask, though, is if there are *any* tests that come out with an answer other than that our students are woefully inadequate in comparision with any other similar group of students elsewhere. If not, perhaps the biggest problem is not with the tests.

I used to think that the best U.S. students were comparable with the best anywhere. But recent tests show that the Japanese are getting performance out of students with an IQ of 110 or so that we get out of those with IQs of 130. If the top 2% of our students are comparable in performance to the top 25% of theirs, we are wasting a critical national resources, and should do something about. So, by all means develop better tests, but don't dismiss what the old, bad tests are saying.

I think the two most important problems in education in this country, from the standpoint of employers, are these: first, the general population is not learning enough in the publicly-funded educational process to function adequately in the workforce, with the result that subsequent educators and employers have to do the job again. This costs a lot and wastes everybody's time. Second, not enough minorities and women are choosing scientific careers. This is a growing problem because they are becoming a larger fraction of the workforce. The two problems are related, because people don't enter a field they feel unqualified for. If mathematics is taught early and well, and if each student is encouraged and enabled to reach his or her full potential, both of these problems can be solved.

Sheila Sconiers

"Along with inadequate preparation, teachers are given what I consider to be, and most people consider to be, inadequate tools to work with, and for the most part, they don't even know it."

I am going to focus my remarks on teachers, and especially elementary teachers because this is the area I know best. This is where I think the problems begin. I think the one thing we have to talk about and acknowledge is what kind of preparation we are giving elementary teachers—what are they doing, what could they be doing, how are we preparing them.

In fact, we have a teaching force which has been teaching in this country about 25 years, which means they will be in place for the next 20 years—the teaching force that will lead our children into the 21st century. Most of these teachers got off the train at about high school geometry. Most of these teachers were caught then in the critical filter and haven't had to learn anything about mathematics since they were in the 10th grade, about 25 to 30 years ago. They then went to a teachers' college where most of them took one math methods course, not a math course, again about 20 years ago. Most of those courses were taught by mathematicians who came from their departments to teach mathematics. Generally, they were not too happy about doing it; they didn't know much about teaching young children.

So with that background, we asked teachers to go in and teach children about math. Their limited math experiences along with the current standardized tests and math textbooks all converged to give teachers a narrow, distorted view of what mathematics is, so it is no surprise that most teachers believe their mathematical mission is to teach arithmetic computation, basically algorithms for addition, subtraction and place value. Along with inadequate preparation, teachers are given what I consider to be, and most people consider to be, inadequate tools to work with, and for the most part, they don't even know it. The primary and often only tool for math instruction is the textbook. Selected word problems from very new and the most popular textbooks used today are examples of these textbook publishers' ideas of what real world mathematics is and what we mean by making math useful to children. Let me read one of my favorite examples.

"The subtle message we give to everybody—the teachers and the students and their parents, who help them with their homework— is that mathematics really isn't useful, mathematics really isn't to be taken seriously."

"The Smith family throws away 84 pounds of trash each day. How many pounds are thrown away in six days?"

I don't know how many of you weigh your trash each day or how many would have exactly the same amount of trash for six consecutive days, but this is what we are asking the children and teachers to take seriously, and unfortunately, too many of them take it seriously. They believe. Here's another one.

"Bob and Brendan are waiting in the lunch line. Bob is three meters away from the lunch counter. Brendan is 335 centimeters away. Who is closest to the lunch counter?"

Now, who is going to measure the distance between one child and another in the lunch counter, do one in meters and one in centimeters, and then figure out who is closest? This is to lead kids into the subtle notion that math is not to be taken seriously. That is what this is all about. Another example says, "One piano solo took 2 and 5/8 minutes to play, the second solo took 4 and 7/8th minutes.. How many minutes did they both take?" I don't know how many of you measure time to the nearest eighth of a minute, but if you do, you can come and write for this textbook publisher. This is a sixth grade publisher.

So you can see that we have teachers whom we did not ask much from mathematically when they came into the profession, we give them tools like this, and we say things like: "Those teachers are not doing things well, they are not teaching mathematics well, they are not bringing higher order thinking skills into the classroom."

The subtle message we give to everybody—the teachers and the students and their parents, who help them with their homework—is that mathematics really isn't useful, mathematics really isn't to be taken seriously. It is something that is a little game imbedded in words like this. For example, the trash thing could be worked into a wonderful example. There are ecological issues that involve mathematics about the amount of garbage any family gets rid of, that a classroom gets rid of. So, it is not as if the subject matter is not there and accessible to young children. It is just that there are too many forces helping teachers evade the issues.

"I would like to see words like development and inservice omitted altogether. I would like them to be a part of what teaching is all about—learning, growing, keeping up, learning from each other. This has to be done consistently and with a certain amount of regularity."

Certainly, I don't mean these remarks to be an indictment of teachers, only that while reforming the curriculum is necessary, it is hardly sufficient. In looking at the history of mathematics education, curriculum reform has actually had little impact (think back to the new math), mainly because teachers teach what they know, and they teach what they believe in, and a few hours of inservice training to accompany a new textbook or a new curriculum are not going to significantly deepen their knowledge or change their beliefs.

I would suggest that we consider two things seriously when we try to upgrade their skills. The first thing is that we look at elementary schools and think realistically about getting people with deeper and more sophisticated knowledge about mathematics into the schools, possibly mathematics specialists teaching math earlier than we do. We now do that in junior high school; we could possibly do it earlier, in fifth or sixth grade.

Another thing that is my personal pipe dream is that we ultimately rethink our view of teaching, that is, the culture of teaching. We must start thinking about inserting into the culture of teaching mechanisms for continual growth and for continual learning. I would like to see words like development and inservice omitted altogether. I would like them to be a part of what teaching is all about—learning, growing, keeping up, learning from each other. This has to be done consistently and with a certain amount of regularity. It can't be every other summer or the occasional afternoon inservice time. It has to be something we all acknowledge. Teachers need regular updating on changes, not only on materials but on teaching techniques. They should be given time regularly to reflect and to grow and to learn from each other and to become essential elements in the change process from the beginning.

But this kind of thing is expensive; it requires not asking teachers to give up their time after school, but building this into the school year and school week. It should be considered seriously because we first have to lay the groundwork for change. It is not enough to have teachers as the end recipient of change. But that is what we do. We worry about what changes should happen in mathematics education and ultimately should be delivered to teachers, rather than keeping them informed all along and having them ready to receive them.

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